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Nutrient Content in Ponderosa Pine Foliage: Seasonal Variation

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Seasonal variation in foliage nutrient content of out-planted ponderosa pine (*Pinus ponderosa Laws.*) seedlings from three northern Great Plains nurseries in each of 3 years was examined.

Foliage nitrogen and potassium levels generally decreased during the growing season. Phosphorus, calcium, and zinc levels remained constant or decreased slightly. Magnesium and manganese levels with two exceptions remained constant or increased slightly. Sulfur levels increased until the middle of the growing season and then decreased.

Differences in foliage nutrient content between nursery sites and years within the study were also significant.

Background

Foliar nutrient analysis has been used routinely in agronomy for two decades, but in forestry, foliar nutrient analysis is used primarily after symptoms of nutrient deficiencies appear. At that point, however, growth loss is already significant.

It is primarily the extended growth period of trees which complicates foliage nutrient analysis. Nutrient levels of tree foliage vary with the tree age, foliage age, and the crown position of the foliage sampled. In addition, foliage nutrient levels vary between years and within a growing season. Despite these sources of variation, nutritional reference standards have been developed for several forest tree species (See Further Reading Section).

Seasonal nutrient variation has been studied for several trees but not for ponderosa pine (*Pinus ponderosa* Laws.). The objectives of the research reported here were: 1) to provide basic information on seasonal variation of foliage nutrient levels in ponderosa pine seedlings, 2) to determine if seasonal variations in those levels may limit survival and growth of ponderosa pine in shelterbelts in South Dakota, and 3) to determine if differences existed between seedlings from three nurseries over a 3-year period.

Plant materials were obtained in each of 3 years from three nurseries in the northern Great Plains, the U.S. Forest Service Bessey Nursery at Halsey, NE, South Dakota Division of Forestry Big Sioux Tree Nursery at Watertown, SD, and the North Dakota Forest Service Towner Nursery at Towner, ND.

Ponderosa pine seedlings from the Bessey Nursery and the Big Sioux Tree Nursery were 2-0 stock. Due to the shorter growing season at the Towner Nursery in North Dakota those seedlings were 3-0. Two hundred and fifty seedlings from each nursery were shipped by common carrier each spring. Upon arrival a random sample of 25 seedlings was taken for mineral nutrient analysis. The remaining 225 seedlings were put into refrigerated storage at 1°C until field planting in Brookings County, South Dakota.

Field planting dates varied from late April to early May due to spring rain conditions. Seedlings were machine planted in 300-ft rows at a spacing of about 18 inches in the row and 8 ft between rows. The soil type was a Lamoure silty clay loam and contained 21 ppm NO_3-N, 9.5 ppm P, 165 ppm K, 30 ppm S, .46% Ca, 930 ppm Mg, 15 ppm Fe, 8.2 ppm Mn, 165 ppm Zn, pH 7.9 and 3.2 percent organic matter.[1]

One week after planting and at monthly intervals thereafter, a random sample of 25 seedlings was taken. The monthly sampling continued until the end of September each year.

The random sample of 25 seedlings was separated into two groups, one for nutrient concentration analysis, and the other for carbohydrate content analysis.

Three replicates of four trees each were analyzed for mineral nutrient levels. To avoid confounding nutrient analysis with dust and soil contamination, seedlings were washed in a detergent solution, rinsed, washed a second time in an ultrasonic cleaner for 2 minutes, then rinsed with de-ionized water and dried in an oven at 70°C for 72 hours. After drying, previous-year needles were removed from the stems and were ground in a Wiley mill to pass through a 20 mesh screen.

Nitrogen determination was done by the Kjeldahl method. Potassium samples were digested in glacial acetic acid and analyzed with a flame photometer. Samples for the remaining seven mineral nutrients were digested in perchloric and nitric acid. Phosphorus and sulphur levels were determined colorimetrically. Calcium, magnesium, zinc, iron, and manganese levels were determined using a Perkins-Elmer Model 372 atomic absorption unit.

Statistical Analysis

Foliage nutrient concentration data for sampling date, year, and nursery source were analyzed for significant differences by analysis of variance (ANOVA). Differences in means of foliage nutrient content between sampling dates within years and nursery source were determined by the Duncan-Waller multiple range test ($p = .05$).

[1]Analyses of soil samples and plant tissue were performed by the Soil Testing and Plant Analysis Laboratory, Plant Science Department, South Dakota State University, Brookings, SD 57007.

Differences in means of foliage nutrient content between years and between nursery sources were also determined using the Duncan-Waller multiple range test ($p = .05$)

RESULTS[2]

Nitrogen

Seasonal variation in total nitrogen (N) concentration of ponderosa pine foliage is shown in Fig. 1. The nitrogen concentration of ponderosa pine foliage on a percent of dry weight basis decreased from the beginning to the end of the sampling period for all three nursery sourc in 1979 and 1980. In 1981 foliage N decreased in the seedlings from the Big Sioux Nursery but did not change in seedlings from Bessey or Towner.

In 1980 and 1981 there was an increase in the foliage N level in seedlings from the Big Sioux Nursery when compared with the 1979 level. Beginning in the summer and fall of 1979 the Big Sioux Nursery changed fertilization practices. This shows up in an increased nitrogen concentration in ponderosa pine foliage beginning in 1980.

Phosphorus

The phosphorus (P) concentration decreased from the beginning to the end of the sampling period for all three nursery sources in 1979 and 1981 (Fig. 2). In 1980, foliage P decreased in seedlings from Halsey but did not show a clear trend in seedlings from Big Sioux or Towner.

Potassium

Seasonal variation in the potassium (K) concentration of ponderosa pine foliage exhibited the same pattern as the nitrogen concentration (Fig. 3). In 1979 and 1980 foliage K decreased throughout the growing season. In 1981 foliage K decreased in seedlings from Big Sioux, but no clear

[2]All results reported are significant at $p = .05$ unless otherwise stated.

trend could be detected in the foliage K of seedlings from Halsey or Towner.

Sulfur

Total sulfur (S) concentration increased in the early part of the growing season. However, September foliage S was no different than initial values, except in the case of seedlings from the Big Sioux Nursery in 1980, where S was higher in September than in April.

Magnesium

Magnesium (Mg) concentration did not show a consistent pattern from year to year (Fig. 5). In 1979, foliage Mg decreased until July or August, then increased. By September, Mg content was no different from the beginning of the sampling period. In 1980, foliage Mg increased until August, then decreased in September to a slightly (but not statistically significant) higher level than initial values. In 1981, foliage Mg levels remained nearly constant throughout the growing season.

Calcium

In 1979 and 1980, calcium (Ca) ended the growing season at the same level as the beginning of the season for all three sources (Fig. 6). In 1981, foliage Ca in seedlings from Big Sioux and Towner decreased significantly while Ca in seedlings from Bessey did not change.

Zinc

In 1979 zinc (Zn) concentration of seedlings from Big Sioux and Towner did not change through the sampling period (Fig. 7). Foliage from seedlings grown at Bessey, however, decreased in Zn concentration. In 1980 and 1981, foliage Zn in seedlings from all three nurseries decreased from the beginning to the end of the sampling period.

Iron

In 1979 and 1981, foliage iron (Fe) concentration from all three nurseries increased (Fig. 8). In 1980, foliage Fe increased but the amount of increase was not significant.

Manganese

In spite of large monthly variations in manganese (Mn) concentration in seedlings from Towner in 1980 and Bessey Nursery in 1981, foliage Mn ended the sampling period no different from the beginning in all three nursery sources for all 3 years (Fig. 9).

Nursery Source Variation

To determine if differences in nutrient concentration existed between nursery sources, data from the first sample date pooled over 3 years was analyzed by ANOVA (Table 1). Seedlings from the Bessey Nursery had higher foliage manganese and lower iron and magnesium. Seedlings from the Big Sioux Nursery had higher nitrogen, calcium, and magnesium and lower zinc and manganese. Seedlings from the Towner Nursery were higher in iron and lower in phosphorus.

Variation Between Years

Statistical analysis of the data also showed a significant difference in foliage nutrient concentration between years (Table 2). However, there was no one year in which all the nutrients were at their highest level.

After pooling the three nursery sources, phosphorus and potassium foliage levels were higher in 1979 than in either 1980 or 1981. Foliage sulfur and magnesium were higher in 1980 than in either 1979 or 1981. Nitrogen, calcium, and manganese levels were highest in 1981. Foliage zinc levels were no different in 1979 and 1980 and were lower in 1981. Foliage iron levels were the same in 1979 and 1981 and lower in 1980.

DISCUSSION AND CONCLUSIONS

Limited data on foliage nutrient levels for ponderosa pine exists. In a U.S. Forest Service Nursery in Colorado, foliage of healthy appearing 2-0 ponderosa pine seedlings contained 20 ppm NO_3-N, .16% P, .43% K, 197 ppm SO_4-S, .32% Ca, 14% Mg, 222 ppm Fe, 161 ppm Mn, 90 ppm Zn, 10 ppm Cu, and 21 ppm B. (Landis 1976).

Another study reported the phosphorus content of ponderosa pine seedlings grown in phosphorus-deficient and phosphorus-fixing soils. A level of .09% P in foliage was found to be adequate (Vlamis and Biswell 1974).

Powers (1983) gave critical foliage nutrient concentrations for five nutrients in current-year needles of ponderosa pine in California. Those critical values were .95% N, .08% P, .48% K, .05% Ca, .05% Mg.

Powers (1974) in a search of literature compiled a list of adequate foliage nutrient levels for conifers in general for many nutrients. Among these values wer .15% S, 10 ppm Zn, 50 ppm Fe and 100 ppm Mn.

From these figures, it is apparent that, in the ponderosa pine seedlings used in this experiment, four nutrients (N, K, S, and Mn) were at some point during the growing season below what Powers listed as critical or adequate levels for these nutrients (Figures 1, 3, 4, and 9).

Foliage nutrient determinations in this study were made on needles formed during the previous year and expressed in terms of percent dry matter or parts per million of oven dry matter. There were two major reasons for using needles formed during the previous year. First, in most instances a sufficient amount of current-year needles was not available. until the July sampling date. Second, for 2-0 ponderosa pine, the dry weight of previous-year needles averaged 90-95% of the total needle dry weight in April and May and 80-85% of the total needle dry weight in September. For the 3-0 ponderosa pine from the Towner Nursery, the dry weight of previous-year needles averaged about 80-85% of the total needle dry weight in April and May and about 75-80% of the total needle dry weight in September.

Typically, growth of ponderosa pine seedlings the first growing season after outplanting is very limited. Average height growth of the seedlings in the field in September averaged only 5 cm. Consequently, dilution of nutrient content by rapid gains or losses in total needle weight was of only minor significance.

It was apparent, however, that transport of some nutrients out of previous year needles was occurring. This is shown by the steady decline during the growing season in the concentration of N, P, and K.

No strong conclusions can be drawn as to whether nutrient deficiencies are, in fact, contributing to the poor survival of ponderosa pine planted in shelterbelts in South Dakota. The results from this study indicate that N, K, S, and Mn should be examined further, since they were often at or below the critical or adequate level given by Powers for those nutrients in conifers.

Given the findings of this study and having seen the increase in foliage N achieved at the Big Sioux Nursery after altering fertilization practices, it would seem advisable that, once critical values are determined, the three nurseries undertake a larger scale foliage nutrient study on ponderosa pine seedlings.

It is difficult to account for year-to-year foliage nutrient variation since there was no one year in which all foliage nutrient levels were at a maximum. This variation implies that a study of foliage nutrient levels at a nursery should be conducted over a minimum of 2 to 3 years.

Table 1. Nutrient content of ponderosa pine foliage averaged [1/] over a 3-year period to show differences due to nursery source.

	% dry matter					ppm		
Source	N	P	K	S	Ca	Mg	Zn	Fe	Mn
Halsey	1.04c	.129b	.463a	.094ab	.340b	.132b	41.87a	140.40b	214.82a
Big Sioux	1.32a	.138a	.451a	.088b	.406a	.162a	25.39c	258.49a	62.04c
Towner	1.12b	.124b	.361b	.100a	.358b	159a	36.07b	287.27a	157.38b

[1/]Means in each column followed by the same letter are not significantly different (p=0.05).

Table 2. Nutrient content of ponderosa pine foliage averaged [1/] over the three nursery sources to show differences due to year.

	% dry matter						ppm		
Year	N	P	K	S	Ca	Mg	Zn	Fe	Mn
1979	1.11b	.149a	.0460a	.089b	.306b	.143b	35.20a	280.78a	107.58c
1980	1.04c	.122b	.420b	.105a	.276b	.176a	36.62a	136.56b	150.89b
1981	1.33a	.122b	.394b	.089b	.523a	.135b	31.52b	268.82a	175.78a

[1/]Means in each column followed by the same letter are not significantly different (p=0.05).

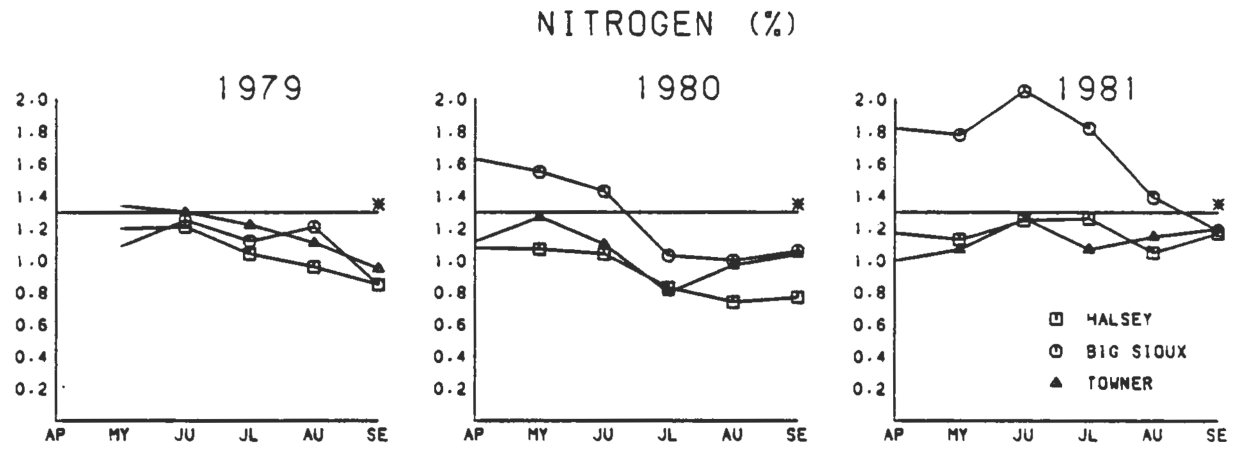

Figure 1. Percent nitrogen in ponderosa pine foliage from three Great Plains nurseries in 1979, 1980, and 1981. *Adequate level taken from Powers (1974).

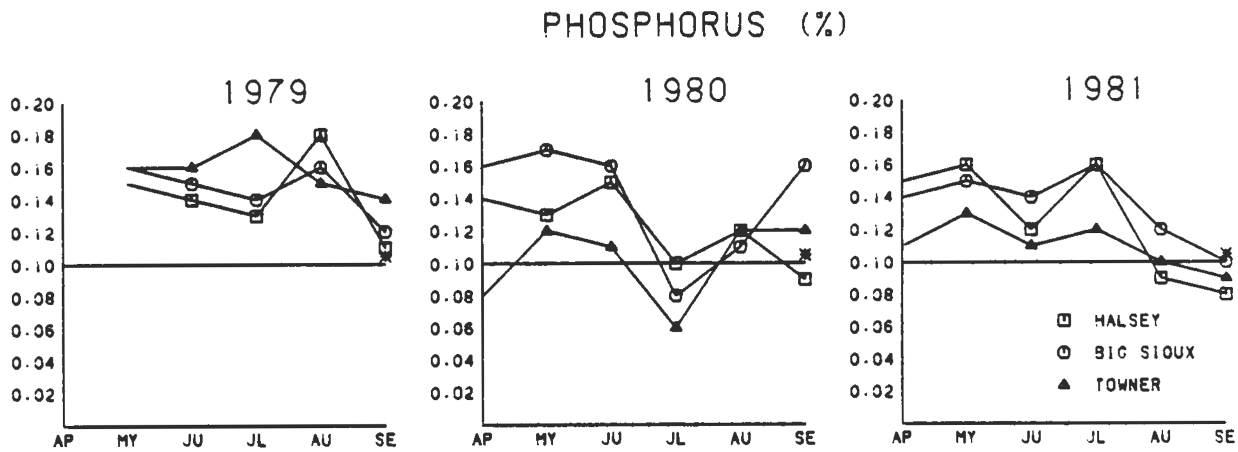

Figure 2. Percent phosphorus in ponderosa pine foliage from three Great Plains nurseries in 1979, 1980 and 1981. *Adequate level taken from Powers (1974).

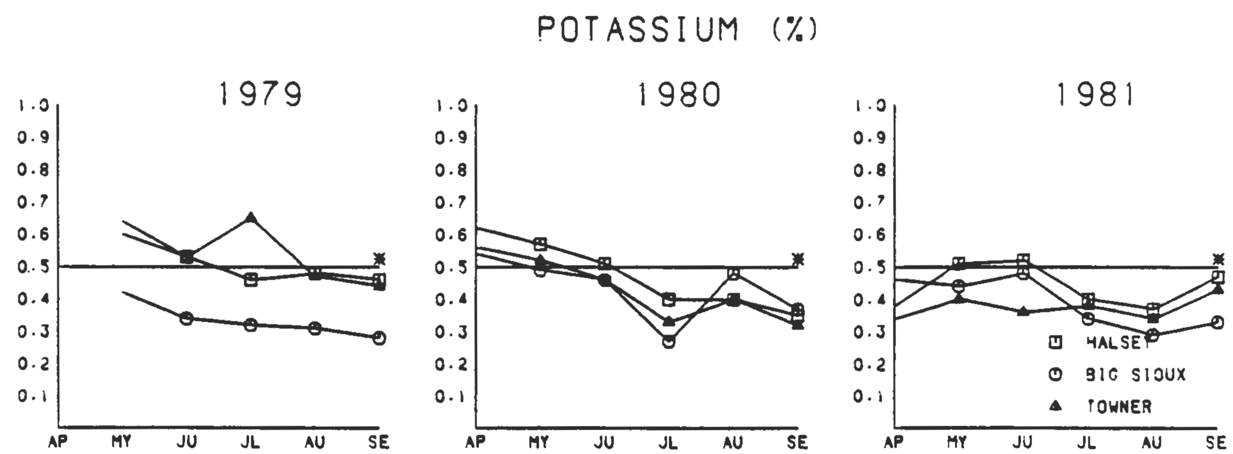

Figure 3. Percent potassium in ponderosa pine foliage from three Great Plains nurseries in 1979, 1980, and 1981. *Adequate level taken from Powers (1974).

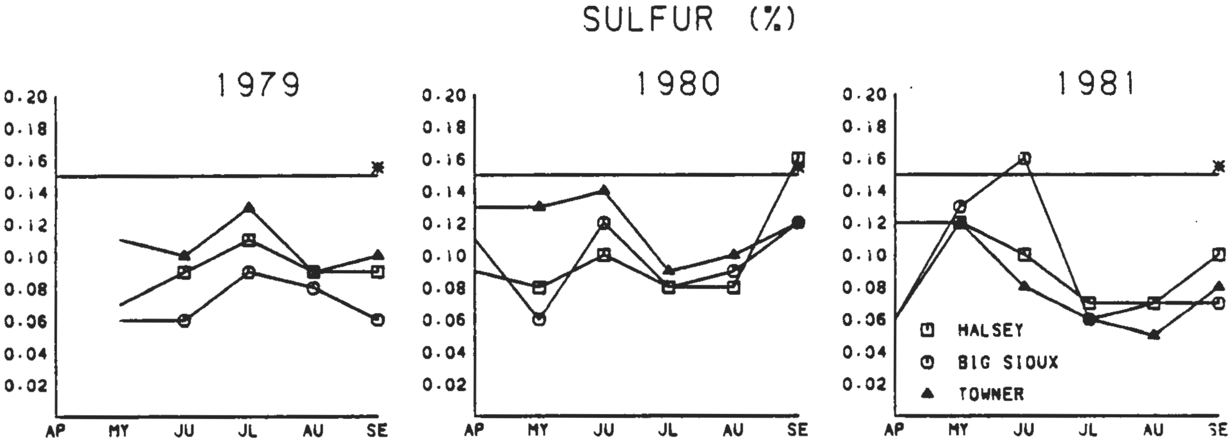

Figure 4. Percent sulfur in ponderosa pine foliage from three Great Plains nurseries in 1979, 1980, and 1981. *Adequate level taken from Powers (1974).

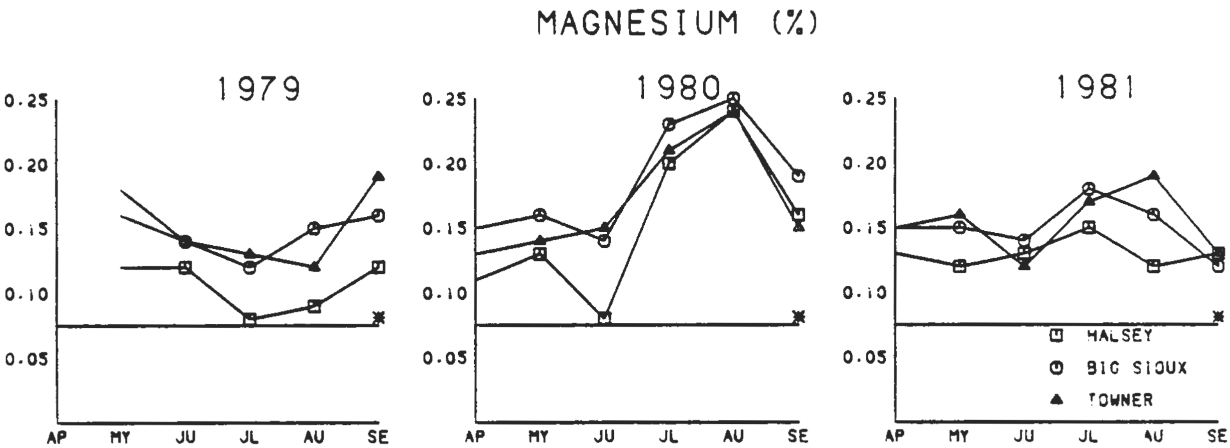

Figure 5. Percent magnesium in ponderosa pine foliage from three Great Plains nurseries in 1979, 1980, and 1981. *Adequate level taken from Powers (1974).

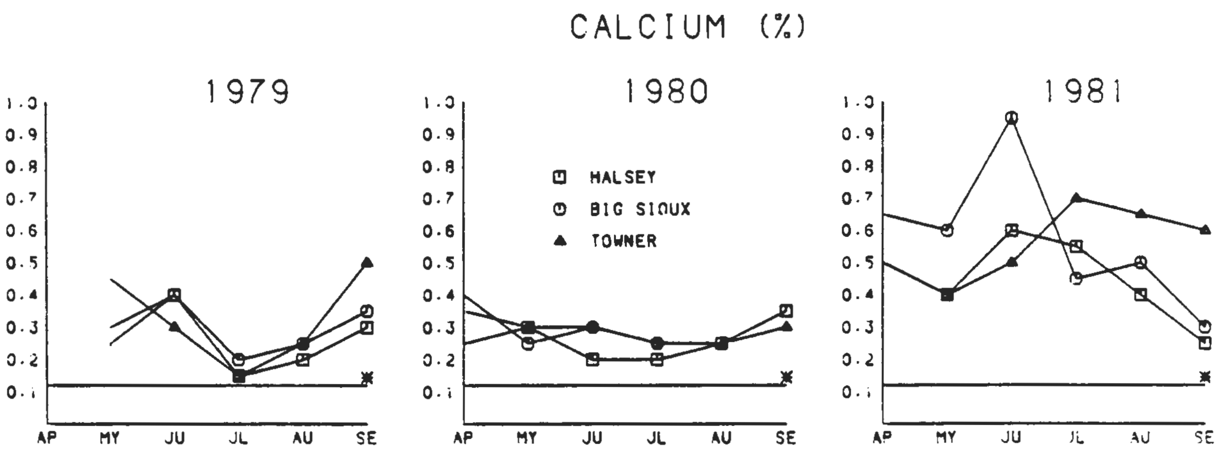

Figure 6. Percent calcium in ponderosa pine foliage from three Great Plains nurseries in 1979, 1980, and 1981. *Adequate level from Powers (1974).

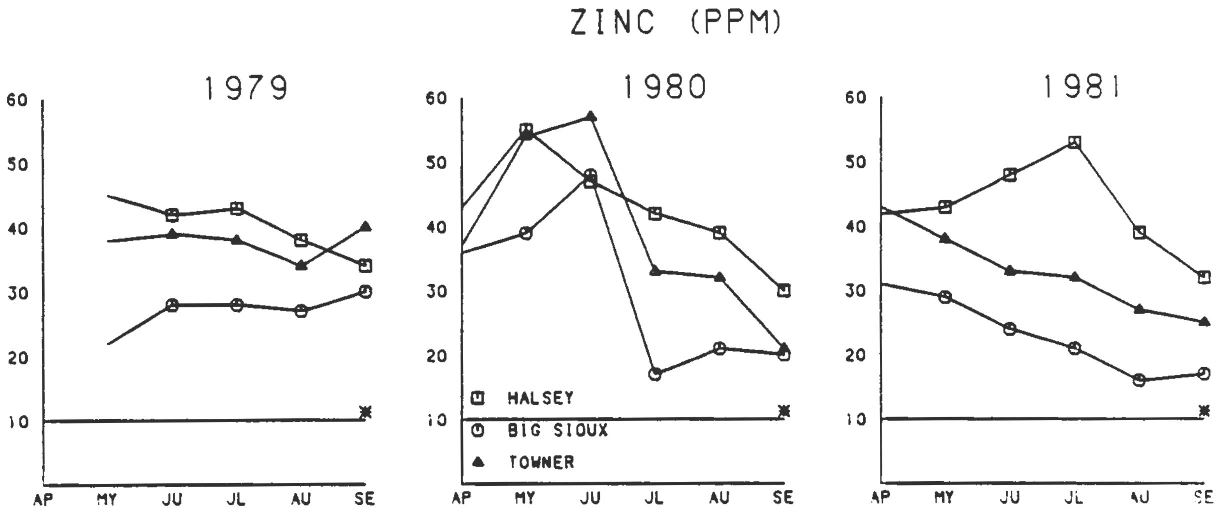

Figure 7. Parts/million zinc in ponderosa pine foliage from three Great Plains nurseries in 1979, 1980, and 1981. *Adequate level from Powers (1974).

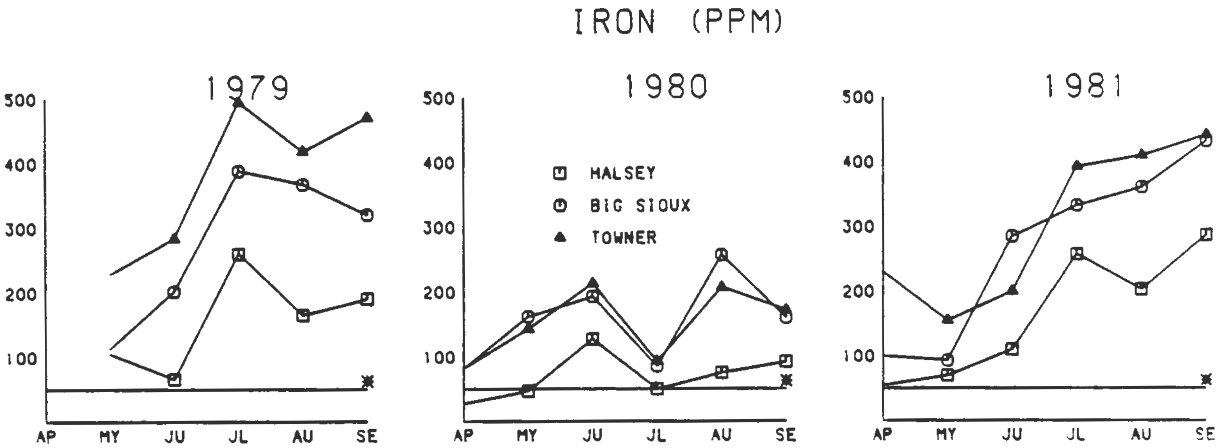

Figure 8. Parts/million iron in ponderosa pine foliage from three Great Plains nurseries in 1979, 1980, and 1981. *Adequate level from Powers (1974).

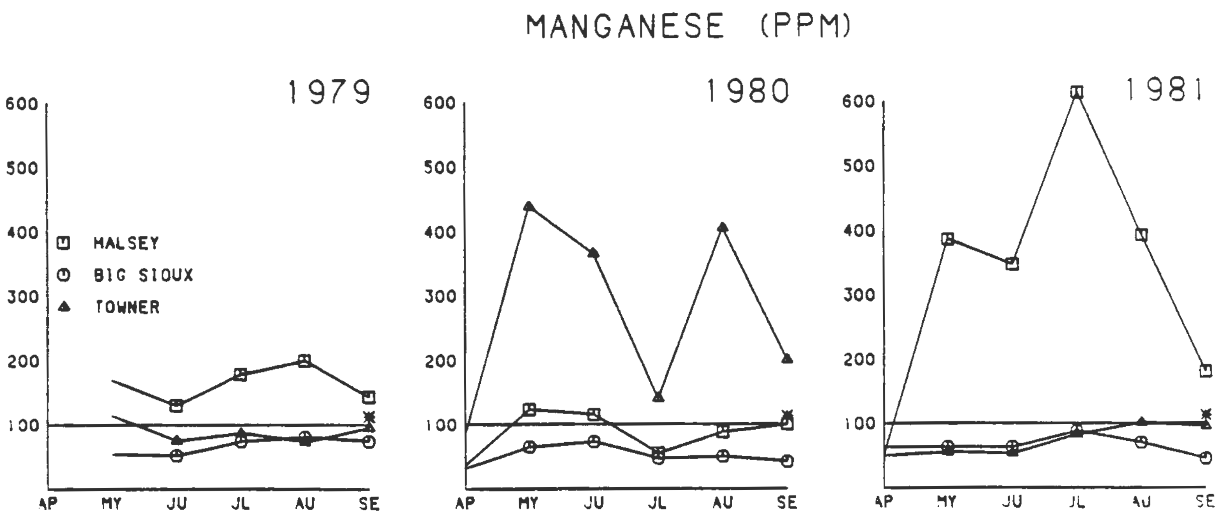

Figure 9. Part/million manganese in ponderosa pine foliage from three Great Plains nurseries in 1979, 1980, and 1981. *Adequate level from Powers (1974).

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Suggested Further Reading

I. Reviews of factors which cause nutrient variations.

Leaf, A.L. 1973. Plant analysis as an aid in fertilizing forest. In Soil Testing and Plant Analysis. L.M. Walsh and J.D. Beaton eds. p. 427-454. Soil Sci. Soc. Amer. Spec. Publ. 2. Madison, Wis.

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Van den Driessche, R. 1974. Prediction of mineral nutrient status of trees by foliar analysis. Bot. Rev. 40:347-394.

II. Foliage nutrient reference standards.

A. Pine

1. Jack pine

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2. Loblolly pine

Fowells, H.A. and R.W. Krause. 1959. The inorganic nutrition of loblolly and Virginia pine with special reference to nitrogen and phosphorus. For. Sci. 5:95-112.

3. Lodgepole pine

Swann, H.S.D. 1972. Foliar nutrient concentrations in lodgepole pine as indicators of tree nutrient status and fertilizer requirement. 19p. Pulp Pap. Res. Inst. Can., Woodlands Pap. 29.

4. Ponderosa pine

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5. Red pine

Leaf, A.L., J.V. Bergulund and R.E. Leonard. 1970. Annual variation in foliage of fertilized and/or irrigated red pine plantations. Soil Sci. Soc. Amer. Proc. 34:677-682.

6. Scotch pine

Ingestad, T. 1979. Mineral-nutrient requirements of *Pinus sylvestris* and *Picea abies* seedlings. Physiol. Plant. 45:373-380.

B. Spruce

1. Black Spruce

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2. Red Spruce

Swann, H.S.D. 1971. Relationship between nutrient supply, growth and nutrient concentration in the foliage of white and red spruce. 27p. Pulp Pap. Res. Inst. Can. Woodlands Pap. 29.

3. White Spruce

Armson, K.A. 1968. The effects of fertilization and seedbed density on the growth and nutrient content of white spruce and red pine seedlings. 10p. Univ. of Toronto, Fac. For. Tech. Rept.

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